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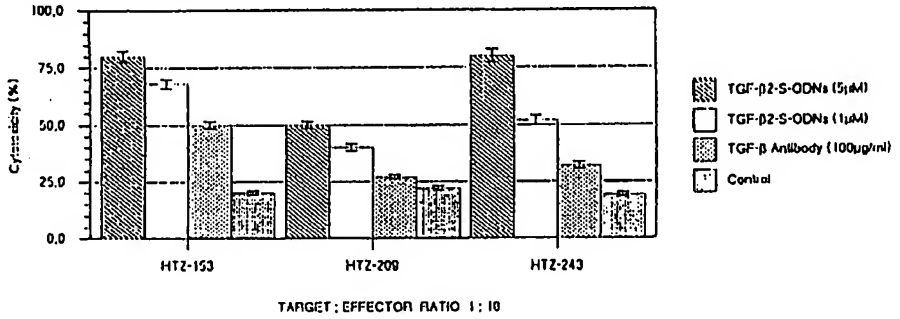
## (54) Antisense-oligonucleotides for the treatment of immuno-suppressive effects of transforming growth factor-b2(TGF-b2)

(57) Antisense-oligonucleotides or effective derivatives thereof hybridizing with an area of a gene coding for transforming growth factor-$\beta_2$ (TGF-$\beta_2$) comprising the following nucleic acid sequences identified in the sequence listing under SEQ ID NO. 57 to 136 each of the nucleic acids having a DNA- or RNA-type structure.




TARGET : EFFECTOR RATIO 1 : 10

FIG. 7

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## Description

**[0001]** The present invention is related to antisense-oligonucleotides or effective derivatives thereof hybridizing with an area of a gene coding for transforming growth factor-β (TGF-β), oligonucleotides as nonsense control nucleotides, a pharmaceutical composition comprising at least one antisense-oligonucleotide or effective derivatives thereof hybridizing with an area of a gene coding for TGF-β as well as a use of antisense-oligonucleotides for the manufacturing of a pharmaceutical composition for the treatment of tumors and/or the treatment of the immunosuppressive effect of TGF-β.

**[0002]** The transforming growth factor-β (TGF-β) is a factor which is, for example, secreted by human glioma cells. Human gliomas such as glioblastoma are human tumors for which at present no satisfactory therapy exists. The TGF-β supports in an autocrine manner the growing of the respective tumor cells. The factor shows immunosuppressive effects and reduces (the proliferation of such cytotoxic T-lymphocytes which otherwise would be able to destroy the glioma cells.

**[0003]** The suppression of immune responsiveness has been well documented in patients with malignant gliomas. These patients express a variety of immunological deficienies including cutaneous anergy, depressed antibody production, diminished numbers of circulating T-cells (Brooks, W. H., Netsky, M. G., Horwitz, D. A., Normansell, D. E. Cell mediated immunity in patients with primary brain tumors, J. Exp. Med., 136: 1931 - 1947, 1972 and Roszman, T., Elliott, L., Brooks, W. Modulation of T-cell function by gliomas, Immunol. Today 12: 370 - 374, 1991). More recent studies indicate that these impairments may result from malfunctions in physiological pathways required for normal T-cell activation and from quantitative and qualitative defects in T-cell subsets.

**[0004]** In Proceedings of the 82nd Annual meeting of the American Association for Cancer Research, Houston Texas, USA, May 15 -18, 1991, Proc AM ASSOC CANCER RES ANNU MEET 32 (O), 1991,, 427 is disclosed that factor-β-antisense-oligonucleotides inhibit a human melanoma cell line under serum-enriched and stimulate under serum-free culture conditions. The results established indicate different roles of cellular TGF-$\beta_1$ in the growth regulation of HTZ-19-cells depending on the amount of serum present in the culture medium. In addition this may indicate the biological potential and possible draw-backs of exogenously administered TGF-β-antisense.

**[0005]** J. EXP. MED. 174 (4), 1991, 925 - 930, Hatzfield J. et al, "Release of early human hematopoietic progenitors from quiescene by antisense transforming growth factor β -1 or Rb oligonucleotides" discloses release of early human hematopietic progenitors from quiescence by antisense transforming growth factor β1 or Rb oligonucleotides. Rb antisense TGF-β negatively regulates the cycling status of early hematopoietic progenitors through interaction with the Rb gene product.

**[0006]** Proceedings of the National Academy of Sciences of USA, Vo. 88, February 1991, Washington US, pages 1516 - 1520, Potts, J. et al., "Epithelialmesenchymal transformation of embryonic cardiac antisense oligodeoxynucleotide to transforming growth factor beta 3" discloses that epithelial-mesenchymal transformation of embryonic cardiac endothelial cells is inhibited by a modified antisense oligodeoxynucleotide to transforming growth factor β3. The transformation depends on the activity of a transforming growth factor β (TGF-β) molecule produced by the heart. Modified antisense oligodeoxynucleotides generated to non-conserved regions of TGF-β1, -2, -3 and -4 were prepared in order to examine the possible roles of these members in this transformation. As a result it has been shown that a specific member of the TGF-β familiy (TGF-β3) is essential for the epithelial-mesenchymal transformation.

**[0007]** WO-A 92/17206 discloses a composition for use in the treatment of wounds to inhibit scar tissue formation during healing comprising an effective activity-inhibitor amount of a growth factor neutralising agent or agents specific against only fibrotic growth factors together with a pharmaceutically acceptable carrier. The method of preparation of said composition and method of administering the composition to a host suffering from tissue wounding is also disclosed.

**[0008]** WO-A 90/09180 discloses methods useful in autologous bone marrow transplantation and cancer therapy. Bone marrow cells from a patient having cancer are treated with selected antisense oligonucleotides in order to deplete the bone marrow of malignant cells prior to infusion back into the bone marrow donor.

**[0009]** It is an object of the present invention to provide a method for the treatment of cancer cells which are correlated with an immunosuppression. Another object of the present invention is to provide an effective agent which inhibits the growth of tumor cells which are related to an immunosuppression.

**[0010]** According to the invention antisense-oligonucleotides or effective derivatives thereof which hybridizes with an area of gene region coding for transforming growth factor-β (TGF-β) comprising the following nucleic acid sequences identified in the sequence listing under SEQ ID NO. 57 to 136 each of the nucleic acids having a DNA- or RNA-type structure are able to solve the problems addressed above. The antisense-oligonucleotide is either able to hybridize with areas of a gene region coding for TGF-β and/or areas of a gene region coding and non coding for TGF-β. For example, some nucleotides of the antisense-oligonucleotide sequence hybridizing with an area of a gene region coding for transforming growth factor-β is hybridizing with an area which does not code for the transforming growth factor whereas, the other part of the respective sequence does hybridize with a gene region coding for TGF-β. Of course, it is also in the

scope of the present invention that the antisense-oligonucleotide hybridizes with an area of a gene region just coding for growth factor-β. It is also understood by the skilled person that fragments having subsequences of the antisense-oligonucleotide works according to the invention so long as production of TGF-β is reduced or inhibited.

**[0011]** In a preferred embodiment of the present invention the antisense-oligonucleotide or effective derivative thereof is a phosphorothioate-oligodeoxynucleotide.

**[0012]** According to the invention the antisense-oligonucleotides are obtainable by solid phase synthesis using phosphite triester chemistry by growing the nucleotide chain in 3'-5' direction in that the respective nucleotide is coupled to the first nucleotide which is covalently attached to the solid phase comprising the steps of

- cleaving 5'DMT protecting group of the previous nucleotide,
- adding the respective nucleotide for chain propagation,
- modifying the phosphite group subsequently cap unreacted 5'-hydroxyl groups and
- cleaving the oligonucleotide from the solid support,
- followed by working up the synthesis product.

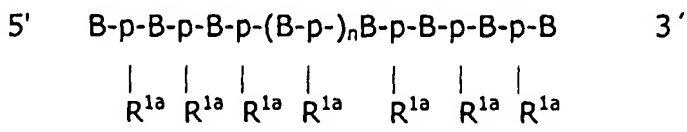
**[0013]** The chemical structures of oligodeoxy-ribonucleotides are given in figure 1 as well as the respective structures of antisense oligo-ribonucleotides are given in figure 2. The oligonucleotide chain is to be understood as a detail out of a longer nucleotide chain.

**[0014]** In figure 1 lit. B means an organic base such as adenine (A), guanin (G), cytosin (C) and thymin (T) which are coupled via N9(A,G) or N1(D,T) to the desoxyribose. The sequence of the bases is the reverse complement of the genetic target sequence (mRNA-sequence). The modifications used are

1. Oligodeoxy-ribonucleotides where all $R^1$ are substituted by

   1.1 $R^1 = O$
   1.2 $R^1 = S$
   1.3 $R^1 = F$
   1.4 $R^1 = CH_3$
   1.5 $R^1 = OEt$

2. Oligodeoxy-ribonucleotides where $R^1$ is varied at the internucleotide phosphates within one oligonucleotide




where

B = deoxy-ribonucleotide dA, dC, dG or dT depending on gene sequence

p = internucleotide phosphate

n = an oligodeoxy-ribonucleotide stretch of length 6 - 20 bases

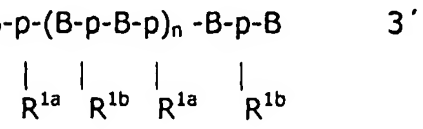
2.1 $R^{1a} = S$ $R^{1b} = O$

2.2 $R^{1a} = CH_3$; $R^{1b} = O$

2.3 $R^{1a} = S$; $R^{1b} = CH_3$

2.4 $R^{1a} = CH_3$; $R^{1b} = S$

3. Oligodeoxy-ribonucleotides where $R^1$ is alternated at the internucleotide phosphates within one oligonucleotide



where

B = deoxy-ribonucleotide dA, dC, dG or dT depending on gene sequence

p = internucleotide phosphate

n = an oligodeoxy-ribodincleotide stretch of length 4 - 12 dinucleotides

3.2 $R^{1a} = S$; $R^{1b} = O$

3.2 $R^{1a} = CH_3$ $R^{1b} = O$

3.3 $R^{1a} = S$; $R^{1b} = CH_3$

4. Any of the compounds 1.1 - 1.5; 2.1 - 2.4; 3.1 - 3.3 coupled at $R^2$ with the following compounds which are covalently coupled to increase cellular uptake

4.1 cholesterol
4.2 poly(L)lysine
4.3 transferrin

5. Any of the compounds 1.1 - 1.5; 2.1 - 2.4; 3.1 - 3.3 coupled at $R^3$ with the following compounds which are covalently coupled to increase cellular uptake

5.1 cholesterol
5.2 poly(L)lysine
5.3 transferrin

In the case of the RNA-oligonucleotides (figure 2) are the basis (adenin (A), guanin (G), cytosin (C), uracil (U)) coupled via N9 (A,G) or N1 (C,U) to the ribose. The sequence of the basis is the reverse complement of the genetic target sequence (mRNA-sequence). The modifications in the oligonucleotide sequence used are as follows
6. Oligo-ribonucleotides where all $R^1$ are substituted by

6.1 $R^1 = O$

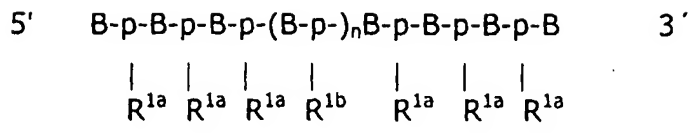
6.2 $R^1 = S$

6.3 $R^1 = F$

6.4 $R^1 = CH_3$

6.5 $R^1 = OEt$

7. Oligo-ribonucleotides where $R^1$ is varied at the internucleotide phosphates within one oligonucleotide



where

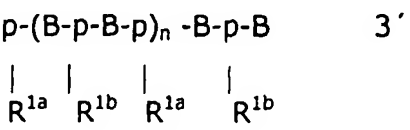
B = ribonucleotide dA, dC, dG or dT depending on gene sequence

p = internucleotide phosphate

n = an oligo-ribonucleotide stretch of length 4 - 20 bases

7.1 $R^{1a}$ = S; $R^{1b}$ = O
7.2 $R^{1a}$ = $CH_3$; $R^{1b}$ = O
7.3 $R^{1a}$ = S; $R^{1b}$ = $CH_3$
7.4 $R^{1a}$ = $CH_3$; $R^{1b}$ = S

8. Oligo-ribonucleotides where $R^1$ is alternated at the internucleotide phosphates within one oligonucleotide



where

B = ribonucleotide dA, dC, dG or dT depending on gene sequence

p = internucleotide phosphate

n = an oligo-ribodinucleotide stretch of length 4 - 12 dinucleotides

8.2 $R^{1a}$ = S; $R^{1b}$ = O
8.2 $R^{1a}$ = $CH_3$; $R^{1b}$ = O
8.3 $R^{1a}$ = S; $R^{1b}$ = $CH_3$

9. Any of the compounds 6.1 - 6.5; 7.1 - 7.4; 8.1 - 8.3 coupled at $R^2$ with the following compounds which are covalently coupled to increase cellular uptake

9.1 cholesterol
9.2 poly(L)lysine
9.3 transferrin

10. Any of the compounds 6.1 - 6.5; 7.1 - 7.4; 8.1 - 8.3 coupled at $R^3$ the following compounds are covalently coupled to increase cellular uptake

10.1 cholesterol
10.2 poly(L)lysine
10.3 transferrin

11. Any of the compounds 6.1 - 6.5; 7.1 - 7.4; 8.1 - 8.3; 9.1 - 9.3; 10.1 - 10.3 where all $R^4$ are substituted by

11.1 $R^4 = O$
11.2 $R^4 = F$
11.3 $R^4 = CH_3$

[0015] Modifications of the antisense-oligonucleotides are advantageous since they are not as fast destroyed by endogeneous factors when applied as this is valid for naturally occurring nucleotide sequences. However, it is understood by the skilled person that also naturally occurring nucleotides having the disclosed sequence can be used according to the invention. In a very preferred embodiment the modification is a phosphorothioat modification.

[0016] The synthesis of the oligodeoxy-nucleotide of the invention is described as an example in a greater detail as follows.

[0017] Oligodeoxy-nucleotides were synthesized by stepwise 5'addition of protected nucleosides using phosphite triester chemistry. The nucleotide A was introduced as 5'-dimethoxytrityl-deoxyadenosine($N^4$-benzoyl)-N,N'-diisopropyl-2-cyanoethyl phosphoramidite (0.1 M); C was introduced by a 5'-dimethoxytrityl-deoxycytidine($N^4$-benzoyl)-N,N'-diisopropyl-2-cyanoethyl phosphoramidite; G was introduced as 5'-dimethoxytrityldeoxyguanosine($N^8$-isobutyryl)-N,N'-diisopropyl-2-cyanoethyl phosphoramidite and the T was introduced as 5'-dimethodytrityl-deoxythymidine-N,N'-diisopropyl-2-cyanoethyl phosphoramidite. The nucleosides were preferably applied in 0.1 M concentration dissolved in acetonitrile.

[0018] Synthesis was performed on controlled pore glass particles of approximately 150 Fm diameter (pore diameter 500 Å) to which the most 3' nucleoside is covalently attached via a long-chain alkylamin linker (average loading 30 Fmol/g solid support).

[0019] The solid support was loaded into a cylindrical synthesis column, capped on both ends with filters which permit adequate flow of reagents but hold back the solid synthesis support. Reagents were delivered and withdrawn from the synthesis column using positive pressure of inert gas. The nucleotides were added to the growing oligonucleotide chain in 3'-> 5 direction. Each nucleotide was coupled using one round of the following synthesis cycle:

cleave 5'DMT (dimethoxytrityl) protecting group of the previous nucleotide with 3-chloroacetic acid in dichloromethane followed by washing the column with anhydrous acetonitrile. Then simultaneously one of the bases in form of their protected derivative depending on the sequence was added plus tetrazole in acetonitrile. After reaction the reaction mixture has been withdrawn and the phosphite was oxidized with a mixture of sulfur ($S_8$) in carbon disulfid/pyridine/triethylamine. After the oxidation reaction the mixture was withdrawn and the column was washed with acetonitrile. The unreacted 5'-hydroxyl groups were capped with simultaneous addition of 1-methylimidazole and acetic anhydryide/lutidine/tetrahydrofuran. Thereafter, the synthesis column was washed with acetonitrile and the next cycle was started.

[0020] The work up procedure and purification of the synthesis products occured as follows.

[0021] After the addition of the last nucleotide the deoxynucleotides were cleaved from the solid support by incubation in ammonia solution. Exoxyclic base protecting groups were removed by further incubation in ammonia. Then the ammonia was evaporated under vacuum. Full-length synthesis products still bearing the 5'DMT protecting group were separated from shorter failure contaminants using reverse phase high performance liquid chromatography on silica $C_{18}$ stationary phase. Eluents from the product peak were collected, dried under vacuum and the 5'-DMT protecting group cleaved by incubation in acetic acid which was evaporated thereafter under vacuum. The synthesis products were solubilized in the deionized water and extracted three times with diethylether. Then the products were dried in vacuo. Another HPLC-AX chromatography was performed and the eluents from the product peak were dialysed against excess of Trisbuffer as well as a second dialysis against deionized water. The final products were lyophilized and stored dry.

[0022] The antisense-oligonucleotides of the invention can be used as pharmaceutical composition or medicament. This medicament can be used for treating tumors in which the expression of TGF-β is of relevance for pathogenicity by inhibiting the transforming growth factor-β and thereby reducing an immunosuppression and/or inhibiting pathological angiogenesis. The reduction of immunosuppression caused by the administration of an effective dose of an antisense TGF-β-oligonucleotides may be accompanied by an augmentated proliferation of cyctotoxic lymphocytes in comparison with the status before administration of the medicament. Thereupon, the lymphocytes are starting their cytotoxic activity decreasing the numbers of tumor cells.

[0023] The medicament of the present invention is further useful for the treatment of endogeneous hyperexpression of TGF-β, for treatment of rest tumors, for treatment of neurofibroma, malignant glioma including glioblastoma and for the treatment and prophylaxis of skin carcinogenesis as well as treatment of esophageal and gastric carcinomas.

[0024] The effect of TGF-$\beta_2$-specific antisense-oligonucleotides on human T cell proliferation and cytotoxicity upon stimulation with autologous cultured glioma cells was investigated. It was demonstrated that TGF-$\beta_2$-derived phosphorothioat-derivatives S-ODN's may specifically inhibit protein expression of TGF-β in glioma cells. In addition, TGF-$\beta_2$-specific S-ODN's revers - to a significant amount - immunosuppressive effects of TGF-β upon T-cell proliferation and

cytotoxicity.

**[0025]** It has been shown that T-cell response in human brain tumor patients is clearly reduced and that tumor infiltrating lymphocytes have only marginal impact upon tumor progression of individual patients (Palma, L., Di Lorenzo, N., Guidett, B. Lymphocytes infiltrates in primary glioblastomas and recidivous gliomas, J. Neurosurg., 49: 854 - 861, 1978 and Ridley, A., Cavanagh, J. B. Lymphocytes infiltration in gliomas, Evidence of possible host resistance. Brain, 4: 117 - 124, 1971). Isolated tumor infiltrating lymphocytes from brain tumors are functionally incompetent, these immunosuppressive effects have been attributed to TGF-$\beta_2$ in vitro and in vivo (Bodmer, S., Stromer, K., Frei, K., Siepl, Ch., de Tribolet, N., Heid, I., Fontana, A., Immunosuppression and transforming growth factor-$\beta_2$ in glioblastoma, J. Immunol., 143: 3222 - 3229, 1989; Couldwell, W. T., Dore-Duffy, P., Apuzzo, M. L. J., Antel, J. P. Malignant glioma modulation of immune function: relative contribution of ifferent soluble factors, J. Neuroimmunol., 33: 89 - 96, 1991; Kuppner, M. C., Hamou, M. F., Sawamura, Y., Bodner, S., de Tribolet, N., Inhibition of lymphocyte function by glioblastoma derived transforming growth factor $\beta_2$, J. Neurosurg., 71: 211 - 217, 1989; Maxwell, M., Galanopoulos, T., Neville-Golden, J., Antoniades, H. N., Effect of the expression of transforming growth factor-$\beta_2$ in primary human glioblastomas on immunsuppression and loss of immune surveillance, J. Neurosurg., 76: 799 - 804, 1992; Palladino, M. A., Morris, R. E., Fletscher Starnes, H., Levinson, A. D., The transforming growth factor betas, A new family of immunoregulatory molecules, Ann. N.Y. Acad. Sci., 59: 181 to 187, 1990; Roszman, T., Elliott, L., Brooks, W., Modulation of T-cell function by gliomas, Immunol Today 12: 370 - 374, 1991).

Figure 3: IGF-β western blot analysis of serum free glioma culture cell lysates. Lanes 2 (HTZ-153), 3 (HTZ-209), and 4 (HTZ-243) indicate blots of respective cell lysates with TGF-$\beta_2$ specific antibody. Lane 1 reprensents a TGF-β positive control employing 50 ng pure TGF-$\beta_2$. TGF-$\beta_2$-antisense treated cells are displayed in lanes A. Untreated control cells are depicted in lanes B. Cells were treated with antisense oligonucleotides for 48 hrs (1 FM final concentration).

Figure 4: TGF-$\beta_2$-mRNA expression in glioma cells. Each lane contained 20 Fg of cytoplasmatic RNA from tumors A (HTZ-153), B (HTZ-209), C (HTZ-243) that hybridized to a $^{32}$P-labeled TGF-$\beta_2$ oligonucleotide probe. To verify equal amounts of RNA, the blot was stained with methylene blue prior to hybridization (A', B', C').

Figure 5: TGF-$\beta_2$-mRNA expression in glioma cells after TGF-$\beta_2$-S-ODN treatment. Cytoplasmatic RNA of untreaated glioma cells A (HTZ-153), B (HTZ-209) and C (HTZ-243) or glioma cells A', B' and C' treated for 48 hours with 1 FM (f.c.) TGF-$\beta_2$-specific S-ODN's under serum-enriched culture conditions, was isolated and processed for Northern blot analysis. Each lane contained 20 Fg of cytoplasmatic RNA hybridized to a $^{32}$P-labeled TGF-$\beta_2$ oligonucleotide probe.

Figure 6: Effect of TGF-$\beta_2$-specific S-ODN's and TGF-β neutralizing antibody on cytotoxicity of PBMC's against autologous cultured glioma cells (target/effector 1 : 10). After 6 days culture of PBMC's with IL-1á and Il-2 the cells were collected, washed, irradiated (30 Gy) and added in target/effector ratios of 1 : 10, 1 : 5, 1 : 1 to autologous glioma cells. Glioma targets were pretreated with either TGF-β specific S-ODN's or TGF-β antibody. Cytotoxicity was assessed employing a modified microcytotoxicity assay. Data are means of triplicate samples, error bars represents SE. Data points reflect individual controls, where tumor targets were treated with medium alone (control). TGF-β antibody (100 Fg/ml), or S-ODN's (1 FM resp. 5 FM) as references for cytotoxicity effects. Thereby, effects upon target cells of antibody or S-ODN's alone could be excluded.

Figure 7: Dose-dependent effects of TGF-$\beta_2$-specific and nonsense S-ODN's on proliferation of lymphocytes, glioma cells and lymphocytes cocultured with autologous glioma cells (MLTC). A: HTZ-153, B: (HTZ-209, C: HTZ-243. PBMC'x were preactivated for 6 days with IL-1á and IL-2 and incubated for additional 6 days with autologous irradiated (60 Gy) and TGF-$\beta_2$-(No.6) and nonsense (no. 5) S-ODSN-treated glioma cells (MLTC). Simultaneously, part of preactivated PBMC's (lymphocytes) and glioma cells (tumor) were incubated with TGF-$\beta_2$ specific (Ly: No. 2, Tu: No. 4) and nonsense) S-ODN's (Ly: No. 1, Tu: No. 3) for 3 days, to evaluate putative direct effects of S-ODN's upon effector- or target cells alone. Proliferation of lymphocytes and glioma cells was assessed employing a $^{3}$H Tdr incorporation assay. Data are means of triplicate samples, error bars represent SE.

**[0026]** The invention is further explained by the following non-limiting examples.

Example 1

Characterization of tumor cells (autologous target cells)

[0027] Tumor cells of 3 patients with high grade malignant gliomas (HTZ-153 and HTZ 209, glioblastomas, HTZ-243, malignant astrocytoma, Gr.III-WHO) and their resp. autologous lymphocytes were studied. Standard tumor cell cultures were established in Dulbecco's Minimal Essential Medium containing 20% fetal calf serum (FCS, Seromed, Berlin, Germany), 1 FM L-glutamine, MEM vitamin solution and nonessential amino acids (GIBCO, Paisley, Scotland, U. K.) (Bogdahn, U., Fleischer, B., Rupniak, H.T.R., Ali-Osman, F. T-cell mediated cytotoxicity in human glioma Biology of Brain Tumor, Martinus Nijhoff Publishers, Boston, 70: 501 - 507, 1986). Other target cells included K562 (an NK-sensitive erythromyeloid leukemic cell line, American Type Culture Collection, Rockville, MD, USA). Tumor cell cultures were characterized by immunocytochemistry employing the PAP-method (Bourne, J. A., Handbook of immunoperoxidase staining methods, DAKO Corporation, Carpinteria CA, USA, 1983) in Labtek tissue culture slides (Miles Laboratories Inc., Naperville, IL, USA) with the following mono- or polyclonal antibodies to: GFAP, Cytokeratin, Neurofilament, Desmin, Vimentin, NSE, HLA, DrO, W6/32 (Class I Antigen), $\beta_2$-Microglobulin, Fibronectin, Laminin, Ki 67 (Dakopatts, Glostrup, Denmark) and anti-TGF-β (R & D Systems, Inc., Minneapolis, MN, USA). TGF-β specific immunocytochemistry was performed after 48 hours incubation of glioma culture slides with 1 FM final concentration (f.c.) TGF-$\beta_2$-specific S-ODN's and 1 FM (f.c.) nonsense S-ODN's treated controls.

Example 2

Characterization of lymphocytes (effector cells)

[0028] Peripheral blood mononuclear cells from all glioma patients were isolated from heparinized venous blood at the day of surgery, employing Ficoll-Hypaque (Pharmacia, Uppsala, Sweden) gradient centrifugation and cryopreserved in liquid nitrogen under standard conditions (Bogdahn, U., Fleischer, B., Rupniak, H.T.R., Ali-Osman, F. T-cell mediated cytotoxicity in human glioma Biology of Brain Tumor, Martinus Nijhoff Publishers, Boston, 70: 501 - 507, 1986). Lymphocytes were cultured in RPMI 1640 (Flow Laboratories Inc., Scotland, U.K.) with 10% human pooled AB-serum (Flow Laboratories Inc. McLean, VA, USA) and 2 mM L-glutamine. Native and activated (see below) peripheral blood mononuclear cells were characterized by immunocytochemistry employing alkaline phosphatase and monoclonal anti-alkaline phosphatase complexes (APAAP-method, Dakopatts GmbH, Hamburg, Germany) (Cordell, J. L., Falini, B., Erber, W. N., et al., Immunoenzymatic labeling of monoclonal antibodies using immune complexes of alkaline phosphatase and monoclonal anti-alkaline phosphatase (APAAP complexes), J. Histochem. Cytochem., 32: 219 - 229, 1984) with monoclonal antibodies to the following antigens: CD3, CD4, CD8, CD16, CD25, HLA DR (Becton Dickinson, Mountain View, Ca USA).

Example 3

LAK-cell generation

[0029] As the proliferative and cytotoxic response of peripheral blood mononuclear cells from glioma patients is suppressed, cells (2 x $10^6$ cells/ml) were preactivated in vitro for 6 days with interleukin-1á (10 U/ml). R & D Systems, Inc., Minneapolis, MN, USA) and interleukin-2 (100 U/ml), BIOTEST AG Frankfurt/M. Germany) in 48 flat bottom tissue culture plates (2 x $10^6$ cells/ml) (Costar, Cambridge, MA, USA).

Example 4

Proliferation assay

[0030] In mixed lymphocyte-tumor cell cultures (MLTC) 15 x $10^3$ lethally irradiated (60 Gy, $^{64}$Co-source) tumor cells served as stimulators, and were cocultivated with 25 x $10^3$ preactivated mononuclear cells (LAK-cells, see above) for 6 days in 96-well-flat bottom tissue culture plates (NUNC, Copenhagen, Denmark). In MLTC-experiments, the same culture medium conditions were employed as during preactivation. In antisense experiments, TGF-$\beta_2$-specific phosphorothioate oligodeoxynucleotides (S-ODN's) and nonsense oligodeoxynucleotides (see below) were added to the cultures 12 hours before MLTC assay. Anti-TGF-β neutralizing antibodies (R & D Systems, Inc. Minneapolis, MN, USA) were added to the culture 2 hours before MLTC.

Example 5

Cytotoxicity assay

[0031] Cytotoxicity experiments were performed with a modified microcytotoxicity assay (Bogdahn, U., Fleischer, B., Rupniak, H.T.R., Ali-Osman, F. T-cell mediated cytotoxicity in human glioma Biology of Brain Tumor, Martinus Nijhoff Publishers, Boston, 70: 501 - 507, 1986). Briefly, 1.5 x $10^3$ target cells were seeded into 96-well flat bottom tissue culture plates. Twelve hours after plating, TGF-$\beta_2$-specific S-ODN's and nonsense oligodeoxynucleotides (anti-sense-controls) were added to the culture. Anti-TGF-$\beta$ neutralizing antibodies and normal rabbit serum (antibody-controls, R & D Systems, Inc. Minneapolis, MN, USA) were added to the culture 22 hours after plating. Various ratios (target/effector ratio of 1 : 1, 1 : 5, 1 : 10 of preactivated effector cells (LAK-cells) were irradiated (30 Gy), and added to respective targets 24 hours after plating for 3 days under standard culture conditions (RPMI 1640 culture medium containing 10 % pooled AB-serum and 2 FM L-Glutamine). No cytotokines were added to the culture during cytotoxicity experiments. An incubation period of 3 days was selected, as statistical evaluation of data turned out to be optimal at this time point. Killing of target cells was demonstrated by incorporation of Trypan blue dye (data not presented). Target cell proliferation in LAK-cell treated targets) was assessed with a standard $^3$H-Thymidine incorporation assay (6-$^3$H-Thymidine, 1 FCi/well, spec. Activity 27 Ci/mmol). Liquid scintillation counting of $^3$H-thymidine incorporation was performed after 18 hours of incubation of cells. The specific cytotoxicity was calculated as:

$$(cpm_{(control)}\text{-}cpm_{(probe)}/cpm_{(control)}) \times 100\%.$$

Example 6

Northern and Western blot analysis

[0032] Cytoplasmatic RNA was prepared by lysing glioma cells treated with 1 FM (f.c.) TGF-$\beta_2$-specific S-ODN's for 48 hours and untreated controls in buffer containing 0.5% NP-40 (Sambrook, J., Fritsch, E. F., Maniatis, T. Molecular cloning. A laboratory manual, 2nd Edition, Cold Spring Harbor Laboratory Press. 1989). For Northern hybridization aliquots of 20 Fg denaturated RNA were separated by electrophoresis on 1% agarose-formaldehyd gel. The quality and quantity of immobilized RNA was verified by methylene-blue staining of the Hybond-N membranes (Amersham/Buchler, Braunschweig, Germany) after transfer. Blots were hybridized overnight with specific TGF-$\beta_1$- or TGF-$\beta_2$-synthetic oligonucleotide probes (40-mer, Oncogen Science, Seattle, USA), 5' labeled with (gamma-$^{32}$P)-ATP employing T4 polynucleotide kinase (Pharmacia, Freiburg, Germany) and exposed to X-ray film.

[0033] For Western blotting, TGF-$\beta$-S-ODN treated (48 hours, 1 FM f. c.) resp. untreated glioma cells were grown in medium containing 10% FCS washed and further cultured in defined serum free medium for 24 hours. The cells were lysed employing a lysis buffer containing NP-40. 30 Fg of total cellular protein were loaded onto each lane of a 12% polyacrylamide-SDS gel. Fractionated proteins were then electroblotted to a nitrocellulose membrane for 20 minutes at 0.8 mA/cm5 as described (Towbin, H., Staehelin, T., Gordon, J. Electrophoretic transfer of proteins from PAGE to nitrocellulose sheets: procedure and some applications, Proc. Natl. Acad. Sci., USA, 76: 4350 - 4354, 1979). Filters were probed with a polyclonal antibody of TGF-$\beta_2$ (R & D Systems Inc. Minneapolis, USA) 50 Fg of TGF-$\beta$ served as control.

Example 7

Phosphorothioate modified antisense oligodeocynucleotides (S-ODN's)

[0034] TGF-$\beta_2$-specific antisense oligodeoxynucleotides (antisense direction of TGF-$\beta_2$ mRNA primer sequene oligonucleotide seequence: CAGCACACAGTACT) and randomized nonsense sequence with the same GC-content as the specific S-ODN's (nonsense oligonucleotide sequence: GTCCCTATACGAAC) were synthesized on an Applied Biosystems model 380 B DNA Synthesizer (Schlingensiepen, K.-H., Brysch, W. Phosphorothioate oligomers. Inhibitors of oncogene expression in tumor cells and tools for gene function analysis in : Erikson, R., Izant., J. (Eds.) Gene regulation by antisense nucleic acids. Raven Press New York 1992). S-ODN's were removed from the solid support with 33 % ammonnia. Oligonucleotides still bearing the 5' trityl protecting group were purified by reverse phase HPLC, with an Aquapore RP-300, C8-column( Brown-lee). Solvents: A - 0.1 M TEAA pH 7, B-Acetonitrile. Gradient 3 - 35% B over 30 Min. linear. Trityl bearing fraction of oligonucleotides, corresponding to the full-length product were detritylated in 80% acetic acid/ETOH for 20 Min. extracted twice with diethyl-ether, desalted on a Sephadex G 25 (Pharmacia) column, ethanol precipitated (2x) and finally diluted in 0.1 M Tris/HCL pH 7.6. S-ODN's were judged from polyacrylamid-gel-electrophoresis to be more than 85% full-length material.

Example 8

Characterization of tumor cells

**[0035]** All glioma cell cultures expressed GFAP, TGF-β, vimentin, and HLA-Class I antigens, as well as β-microglobulin, fibronectin, and KI 67, inconsistent expression was found with desmin, HLA-Class II antigen (positive: HTZ-209) and NSE (positive: HTZ-209, HTZ-243). No expression was found for cytokeratin, laminin and neurofilaments, indicating the glial origin of these tumor cells.

**[0036]** Western blot analysis of tumor cell lysates revealed that HTZ-153, HTZ-209 and HTZ-243 cells produced TGF-$\beta_2$ protein (Figure 3).

**[0037]** Northern blot analysis of cytoplasmatic RNA's from all 3 tumros revealed message for TGF-$\beta_1$ (2.3 kB) and TGF-$\beta_2$ (4.1 kB) (Figure 5): message for TGF-$\beta_1$ was fairly well represented in all three tumors (Figure 4), however, tumor HTZ- 209 displayed a faint TGF-$\beta_2$ signal compared to the remaining tumors (Figure 5).

Example 9

Modulation of TGF-β expression by treatment of glioma cells with TGF-$\beta_2$ specific S-ODN's

**[0038]** The effects of TGF-$\beta_2$-specific S-ODN-treatment upon TGF-$\beta_2$ mRNA- and -protein expression in glioma cells were analysed by Northern blotting. Western Blotting and immunocytochemistry. Northern blot analysis of glioma cells treated with TGF-$\beta_2$-specific S-ODN's (f.c. 1 FM for 48 hours) yielded inconsistent results: HTZ-153 displayed an increase in TGF-$\beta_2$-message, whereas tumors HTZ-209 and HTZ-243 showed no detectable message following antisense oligodeoxynucleotides treatment (Figure 6). Western blot analysis revealed a decreased TGF-$\beta_2$-specific signal for all 3 tumors after S-ODN treatment (Figure 3).

**[0039]** Immunostaining of glioma cultures treated with TGF-$\beta_2$-specific S-ODN's (f.c. 1 FM for 48 hours) revealed a decrease of TGF-β-dependant immunoreactivity compared to nonsense S-ODN-treated and untreated controls for all 3 tumors. Controls with normal mouse serum and human AB-serum were negative (slides not presented).

Example 10

Characterization of lymphocytes

**[0040]** Autologous effector lymphocytes employed in the following experiments on tumor dependant lymphocyte proliferation and glioma cytotoxicity were characterized by conventional lymphocyte differentiation antigens. Data of characterization experiments are displayed in table 1, cell populations reflect the phenotype of lymphocyte subsets of native (Day 0) and activated (Day 6) effector cells, employed in proliferation and cytotoxicity experiments. The percentage of $CD3^+$ cells increased during culture time, up to 85%. The same was true for $CD4^+$ (up to 80%). $CD8^+$ (up to 18), $CD25^+$ (up to 60%)-cells, the fraction of $CD16^+$ cells increased to a maximum of 50% (HTZ-243) during the first 6 days of culture.

Example 11

Cytotoxicity experiments

**[0041]** Native PBMC's of tumor-patients investigated in our study expressed low cytotoxic activity to autologous targets, (below 20% at target/effector ration 1 : 10. Preliminary experiments disclosed that preactivation of autologous effector PBMC's was most effective, when cells were incubated with 10 U/ML IL-1á adn 100 U/ml IL-2 for 6 days. These LAK-cells were employed in all further cytotoxicity/proliferation experiments.

**[0042]** At a target/effector ration of 1/10, LAK cells achieved a cytotoxic activity of up to 25% in the autologous target systems (Figure 7). Preincubation of tumor cells with neutralizing TGF-β antibodies (f.c. 100 Fg/ml) resulted in a cytotoxicity of 30% - 50% (5 - 30% increase above the untreated controls) (Figure 7). When tumor cells were preincubated with TGF-$\beta_2$-specific antisense S-ODN's cytotoxicity increase in a dose dependent fashion to a maximum of 79% (5 FM S-ODN's, 25 - 60% increase above untreated controls) and 67% (1 FM S-ODNs, 15 - 45% increase above untreated autologous lymphocytes. All three effector cell populations expressed high NK-activity as detected by cytotoxicity assay against K 562 cell line, ranging from 60% to 75%.

Example 12

Proliferation experiments

**[0043]** Lymphocyte proliferation upon stimulation with autologous tumor cells (MLTC) treated with TGF-$\beta_2$-specific S-ODNs was increased in tumors HTZ-153 (Figure 8a) and HTZ-209 (Figure 8b), however, no effect was observed in HTZ-243 cells (Figure 8c). Nonsense S-ODN's at a final concentration (f.c.) of 1 FM did not alter lymphocyte proliferation (Figure 8). Effects of TGF-$\beta_2$-specific S-ODN's were observed in a doese dependant fashion from 0.1 FM up to 1 FM, higher concentrations (5 FM) displayed non-specific toxicity towards PBMC's and tumor cells (Figure 8): the proliferation of PBMC's in S-ODN treated MLTC's and tumor cells (Figure 8): the proliferation of PBMC's in S-ODN treated MLTC's was persistently lower for oligonucleotide concentrations above 1 FM. High concentrations of neutralizing TGF-β antibody (100 Fg/ml) did not enhance lymphocyte proliferation. TGF-$\beta_2$-specific antisense S-ODN's had an inhibitory effect upon proliferation of either cultured lymphocyte populations (marginal effect) or autologous target cells (Figure 8) achieving a maximum of 75% at a S-ODN's concentration of 5 FM (f.c.). Less profound inhibitory effects were observed with randomized control nonsense S-ODN's (average 20%, up to 40% at 5 FM f.c.).

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## Claims

1. Antisense-oligonucleotides or effective derivatives thereof hybridizing with an area of a gene coding for transforming growth factor-$\beta_2$ (TGF-$\beta_2$) comprising the following nucleic acid sequences identified in the sequence listing under SEQ ID NO. 57 to 136 each of the nucleic acids having a DNA- or RNA-type structure.

2. Antisense-oligonucleotide according to claim 1 wherein the antisense-oligonucleotide is a phosphorothioate oligodeoxynucleotide.

3. Antisense-oligonucleotide according to claim 1 and/or 2 obtainable by solid phase synthesis using phosphite triester chemistry by growing the nucleotide chain in 3'-5' direction in that the respective nucleotide is coupled to the first nucleotide which is covatently attached to the solid phase comprising the steps of

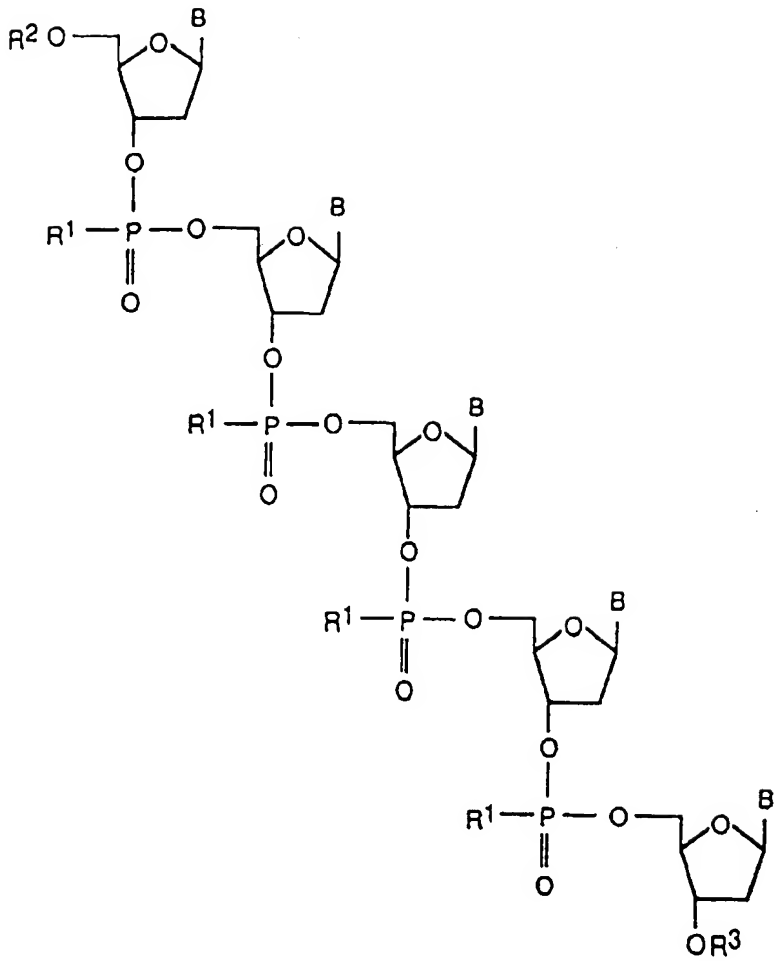
   - cleaving 5'DMT protecting group of the previous nucleotide,
   - adding the respective nucleotide for chain propagation,
   - modifying phosphite groups subsequently cap unreacted 5'-hydroxyl groups and
   - cleaving the oligonucleotide from the solid support,
   - followed by working up the synthesis product.

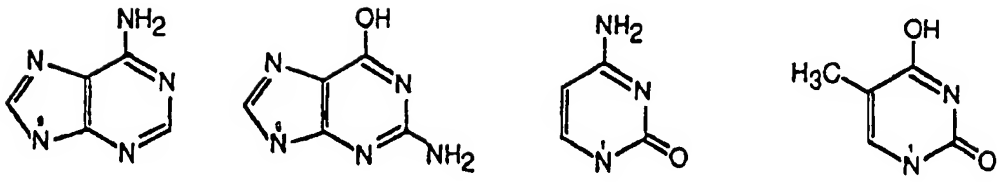
4. Antisense-oligonucleotide according to any on of the claims 1 to 3 wherein the oligonucleotides of the SEQ ID NO. 57 to 136 are phosphorothioate-antisense-oligodeoxynucleotide of TGF-$\beta_2$.

5. Pharmaceutical composition comprising an antisense-nucleic acid according to any one of the claims 1 to 4.

6. Use of antisense-oligonucleotides according to any one of the claims 1 to 4 for the manufacturing of a pharmaceutical composition of claim 5 for the treatment of tumors in which expression of TGF-$\beta$ is of relevance for pathogenicity and/or inhibition of pathological angiogenesis.

7. Use according to claim 6 for manufacturing pharmaceutical composition for the treatment of the immunosuppressive effect of TGF-β, augmentation of the proliferation of cytotoxic lymphocytes, for the treatment of endogenous hyper expression of TGF-β, for treatment of breast tumors, for treatment of neurofibroma, malignant glioma inculding glioblastoma for the treatment and prophylaxis of skin carcinogenesis as well as treatment of esophageal and gastric carcinomas.




Adenine Guanine Cytosine Thymine

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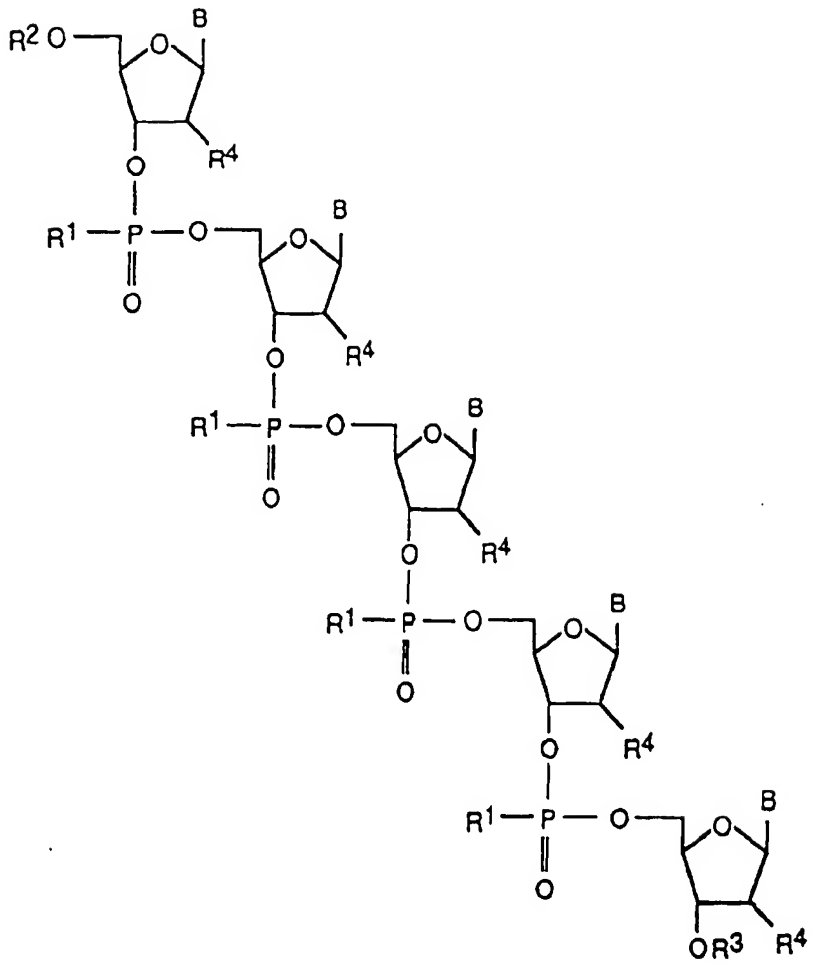

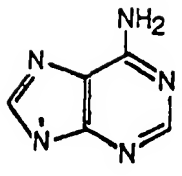

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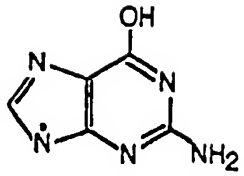

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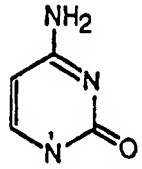

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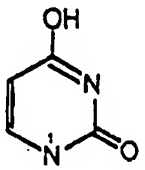

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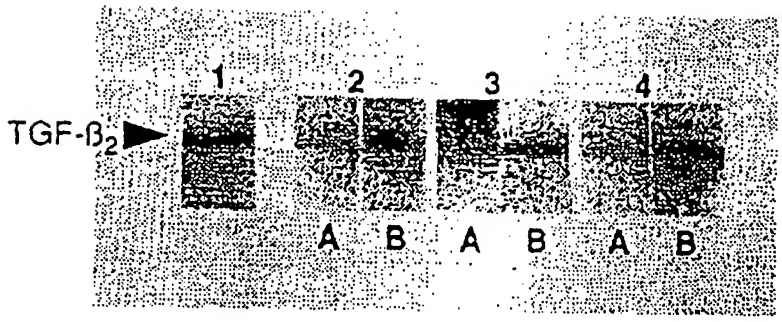


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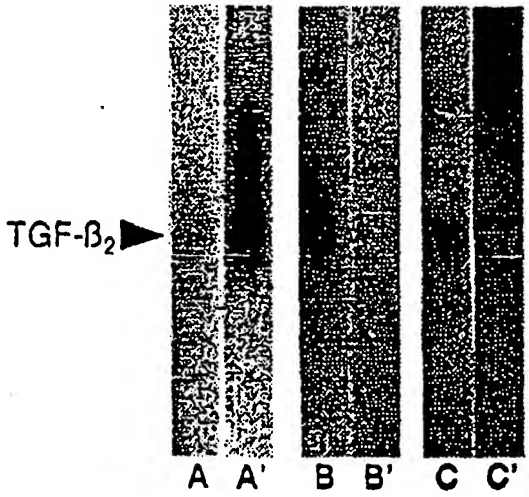


FIG. 6

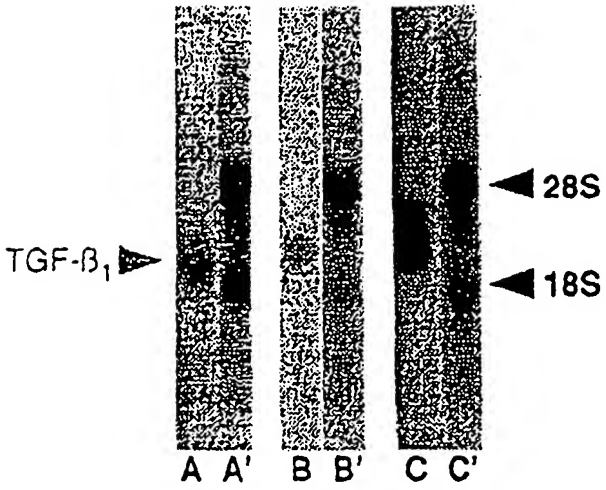


FIG. 4

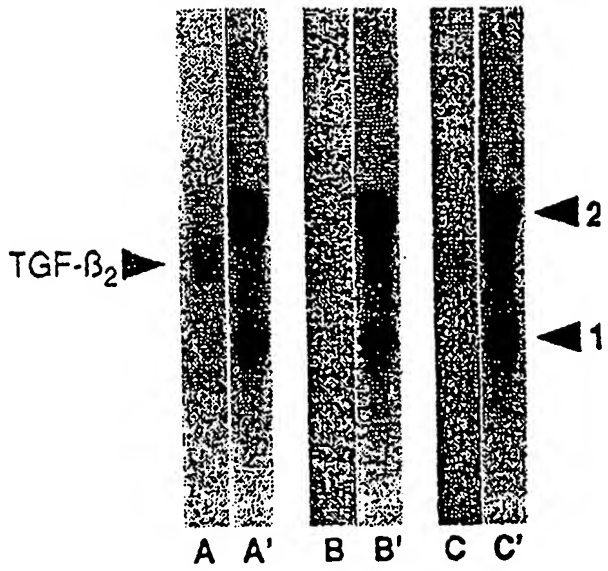


FIG. 5

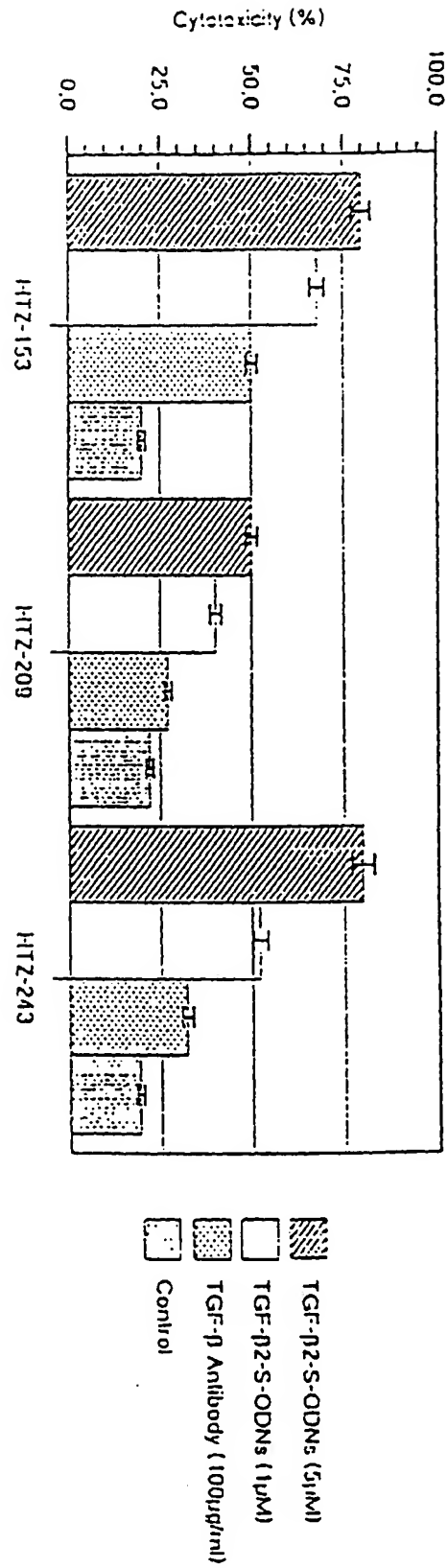
Cytotoxicity (%)
100.0
75.0
50.0
25.0
0.0
HTZ-153
HTZ-209
HTZ-243
TARGET : EFFECTOR RATIO 1 : 10
TGF-β2-S-ODNs (5μM)
TGF-β2-S-ODNs (1μM)
TGF-β Antibody (100μg/ml)
Control

FIG. 7

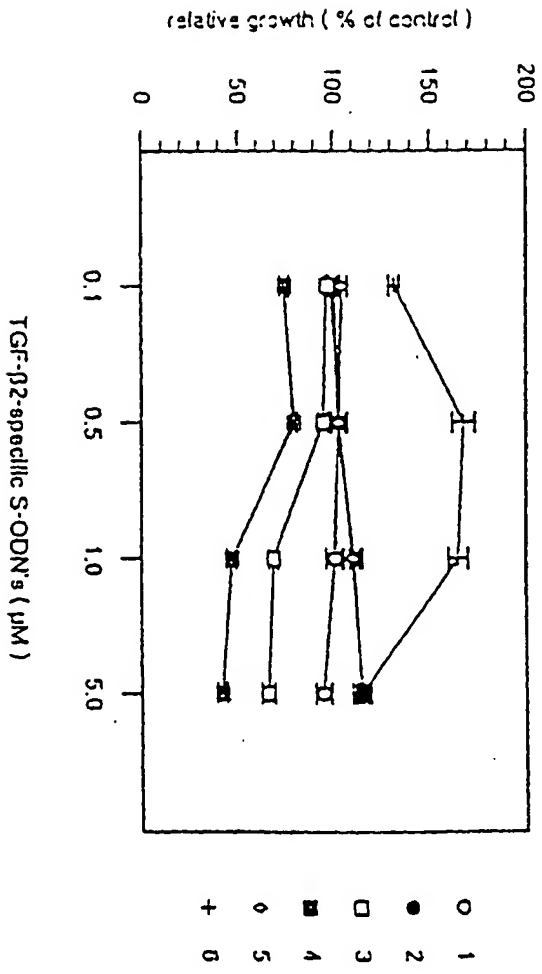
relative growth ( % of control )
0
50
100
150
200
TGF-β2-specific S-ODN's ( μM )
0.1
0.5
1.0
5.0
+
◇
■
□
●
○
0
5
4
3
2
1

FIG. 8a

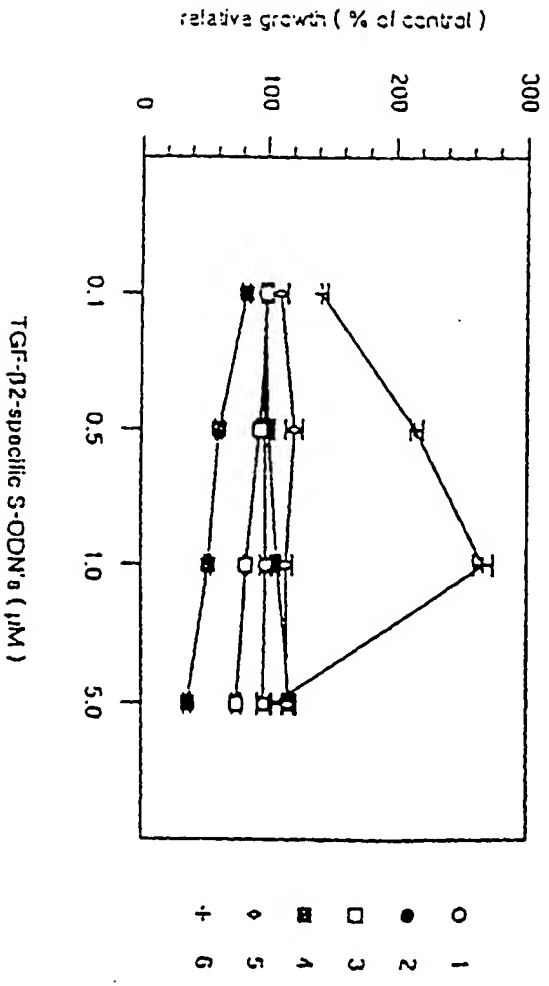
relative growth ( % of control )
0
100
200
300
TGF-β2-specific S-ODN's ( μM )
0.1
0.5
1.0
5.0
1
2
3
4
5
6

FIG. 8 b

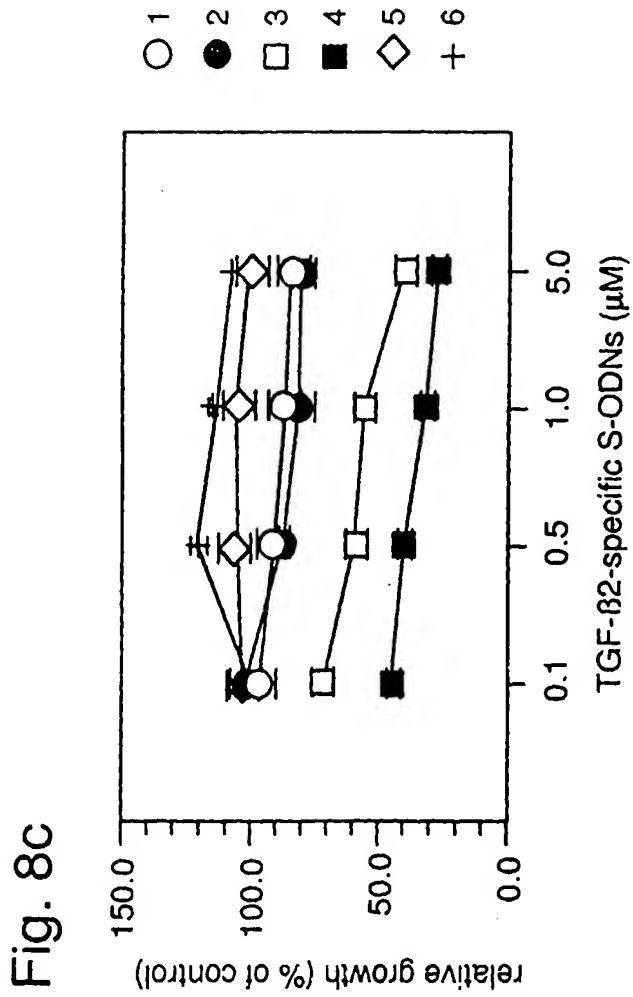
1
2
3
4
5
6
150.0
100.0
50.0
0.0
relative growth (% of control)
0.1
0.5
1.0
5.0
TGF-β2-specific S-ODNs (μM)

Fig. 8c